

What is Claimed is:

1. An adaptive antenna control method used for a
2 radio communication system built by a plurality of radio
3 base stations and a plurality of terminal stations
4 capable of communicating with the radio base stations,
5 each radio base station including an adaptive antenna
6 having a plurality of antenna elements, a distributor
7 for generating signals to be input to the plurality of
8 antenna elements by branching a signal of one system to
9 be transmitted, and weighting circuits for respectively
10 weighting transmission signals to the plurality of
11 antenna elements, wherein
12 for reception by each terminal station, an
13 interference wave power given by the transmission signal
14 from each of the plurality of radio base stations is
15 estimated, and
16 a weight in the adaptive antenna of each radio
17 base station is determined to minimize a sum of square
18 errors between reception signals and desired signals for
19 all the radio base stations which simultaneously use the
20 same communication channel.

2. A method according to claim 1, wherein a
2 predetermined known signal is transmitted from each of
3 the plurality of radio base stations to each terminal
4 station, and in each terminal station, a transfer

5 function is obtained for each radio base station by
6 checking a correlation between the known signal and the
7 reception signal actually received from each radio base
8 station, and the interference wave power is estimated on
9 the basis of the transfer function.

3. A method according to claim 2, wherein the
2 transfer function obtained in each terminal station is
3 transferred to an intensive control station connected to
4 each of the plurality of radio base stations through a
5 wired communication line or wireless communication
6 channel, and the intensive control station determines
7 the weight in the adaptive antenna of each radio base
8 station.

4. A method according to claim 2, wherein a sum
2 result obtained by totaling, for all the antenna
3 elements, for all the radio base stations except a
4 station which transmits a target signal, and for the
5 plurality of terminal stations, the interference wave
6 powers obtained from the transfer functions obtained for
7 the antenna elements of the radio base stations and the
8 weights applied to the antenna elements in transmission
9 is used as an evaluation value of the interference wave
10 power.

5. A method according to claim 2, wherein

2 equation (1) representing a weight vector $Wd(n)$ of a
 3 transmission system, which is to be given to the
 4 weighting circuit of the adaptive antenna of an n th
 5 radio base station, and equation (2) representing a gain
 6 $G(m)$ of an m th terminal station, which is obtained by a
 7 directional pattern generated by the adaptive antenna,
 8 are alternately repeatedly calculated, and the weight
 9 vector $Wd(n)$ of a calculation result which has converged
 10 is given to each weighting circuit:

$$11 \quad Wd(n) = G(m) \left(\sum_{k=1}^K G(k)^2 Vd(k,n) Vd(k,n)^H \right)^{-1} Vd(m,n) \quad \dots (1)$$

$$12 \quad G(m) = \frac{\text{Re}(Wd(n)^H Vd(m,n))}{\sum_{k=1}^N (Wd(k)^H Vd(m,k) Vd(m,k)^H Wd(k)) + |\sigma(m)|^2} \quad \dots (2)$$

14 where

15 $\sigma(m)$: noise power of m th terminal station

16 Re : real number portion

17 suffix H: complex conjugate transposition

$$18 \quad Wd(n) = \begin{pmatrix} wd(n,1) \\ wd(n,2) \\ \vdots \\ wd(n,P) \end{pmatrix}$$

21 $wd(n,1)$ to $wd(n,P)$: weights for antenna
 22 elements

23 P: number of antenna elements of n th base
 24 station

25 $Vd(m,n)$: transfer function vector of downlink

26 communication between mth terminal station and
27 nth base station

$$\begin{array}{l} 28 \\ 29 \\ 30 \end{array} \quad Vd(m,n) = \begin{pmatrix} vd(m,n,1) \\ vd(m,n,2) \\ \vdots \\ vd(m,n,P) \end{pmatrix}$$

31 $vd(m,n,1)$ to $vd(m,n,P)$: transfer functions of
32 antenna elements

33 N: number of base stations

34 K: number of terminal stations

35 Assume communication between nth base station
36 and mth terminal station

6. An adaptive antenna control method used for a
2 radio communication system built by a plurality of radio
3 base stations and a plurality of terminal stations
4 capable of communicating with the radio base stations,
5 each radio base station including an adaptive antenna
6 having a plurality of antenna elements, weighting
7 circuits for respectively weighting reception signals of
8 the plurality of antenna elements, and a signal
9 combining circuit for combining the reception signals of
10 the antenna elements weighted by the weighting circuits,
11 wherein

12 for reception by each radio base station, an
13 interference wave power given by a transmission signal
14 from each of the plurality of terminal stations is

15 estimated, and
16 at least a weight in the adaptive antenna of
17 each radio base station and a transmission power of each
18 terminal station are determined to minimize a sum of
19 square errors between reception signals and desired
20 signals for all the terminal stations which
21 simultaneously use the same communication channel.

7. A method according to claim 1, wherein a
2 predetermined known signal is transmitted from each of
3 the plurality of terminal stations to each radio base
4 station, and in each radio base station, a transfer
5 function is obtained for each terminal station by
6 checking a correlation between the known signal and the
7 reception signal actually received from each terminal
8 station, and the interference wave power is estimated on
9 the basis of the transfer function.

8. A method according to claim 6, wherein the
2 transfer function obtained by each radio base station is
3 transferred to an intensive control station connected to
4 each of the plurality of radio base stations through a
5 wired communication line or wireless communication
6 channel, and the intensive control station determines
7 the weight in the adaptive antenna of each radio base
8 station.

9. A method according to claim 7, wherein a sum
 2 result obtained by totaling, for all the antenna
 3 elements, for all the terminal stations except a station
 4 which transmits a target signal, and for the plurality
 5 of radio base stations, the interference wave powers
 6 obtained from the transfer functions obtained for the
 7 antenna elements of the radio base stations and the
 8 weights applied to the antenna elements of a receiving
 9 station is used as an evaluation value of the
 10 interference wave power.

10. A method according to claim 7, wherein
 2 equation (3) representing a weight vector $Wu(n)$ of a
 3 reception system, which is to be given to the weighting
 4 circuit of the adaptive antenna of an n th radio base
 5 station, and equation (4) representing a transmission
 6 power $Gt(m)$ of an m th terminal station are alternately
 7 repeatedly calculated, and the weight vector $Wu(n)$ of a
 8 calculation result which has converged is given to each
 9 weighting circuit:

$$10 \quad Wu(n) = Gt(m) \left(\sum_{k=1}^K Gt(k)^2 Vu(k, n) Vu(k, n)^H \right)^{-1} Vu(m, n) \quad \dots (3)$$

$$11 \quad Gt(m) = \frac{Re(Wu(n)^H Vu(m, n))}{\sum_{k=1}^N (Wu(k)^H Vu(m, k) Vu(m, k)^H Wu(k)) + (Wu(n)^H Wu(n) |\sigma(m)|^2)}$$

$$12 \quad \dots (4)$$

14 where

15 $\sigma(n)$: input noise power of nth base station
 16 $Wu(n)$: weight vector of nth adaptive antenna
 17 system
 18 Re : real number portion
 19 suffix H: complex conjugate transposition

$$Wu(n) = \begin{pmatrix} wu(n,1) \\ wu(n,2) \\ \vdots \\ wu(n,P) \end{pmatrix}$$

20
 21
 22
 23 $wu(n,1)$ to $wu(n,P)$: weights for antenna
 24 elements
 25 P : number of antenna elements of nth base
 26 station
 27 $Vu(m,n)$: transfer function vector of uplink
 28 communication between mth terminal station and
 29 nth base station

$$Vu(m,n) = \begin{pmatrix} vu(m,n,1) \\ vu(m,n,2) \\ \vdots \\ vu(m,n,P) \end{pmatrix}$$

30
 31
 32
 33 $vu(m,n,1)$ to $vu(m,n,P)$: transfer functions of
 34 antenna elements
 35 N : number of base stations
 36 K : number of terminal stations
 37 Assume communication between nth base station
 38 and mth terminal station

11. An adaptive antenna transmission/reception
2 characteristic control method wherein
3 when a plurality of terminal stations are
4 present in a radio zone where a plurality of radio base
5 stations each having an antenna are present, and at
6 least two of the plurality of terminal stations are
7 transmitting/receiving radio wave signals to/from
8 different radio base stations using the same
9 communication channel with the same signal
10 transmission/reception frequency and same signal
11 transmission/reception timing, at least one of a
12 transmission signal from each of the terminal stations
13 and a reception signal at each of the terminal stations,
14 which is received by and transmitted from each of the
15 terminal stations, is received through the plurality of
16 radio base stations, and
17 a directivity characteristic of the antenna of
18 each base station is changed on the basis of the
19 received signals to reduce an interference power between
20 the terminal stations.

12. A method according to claim 11, wherein
2 the transmission/reception signals of the
3 terminal stations using the same communication channel,
4 which are received through the radio base station, are
5 transferred to an intensive control station, and
6 the intensive control station generates, on

7 the basis of the transferred signals, a control signal
8 for reducing the interference power between the terminal
9 stations and transmits the control signal to each radio
10 base station, thereby changing the directivity
11 characteristic of the antenna of each radio base station.

13. A method according to claim 12, wherein the
2 intensive control station obtains a field strength and
3 spatial correlation characteristic of each radio base
4 station on the basis of the transferred signals and, on
5 the basis of the obtained field strength and spatial
6 correlation characteristic, determines a base station
7 whose directivity characteristic of the antenna is to be
8 changed.

14. A method according to claim 11, wherein each
2 radio base station having an adaptive antenna comprising
3 the antenna formed from a plurality of antenna elements
4 and weighting circuits for respectively weighting
5 transmission/reception signals of the plurality of
6 antenna elements, and the weighting circuits weight the
7 transmission/reception signals transmitted/received
8 from/by the plurality of antenna elements, thereby
9 changing the directivity characteristic of the antenna.

15. A method according to claim 14, wherein
2 upon receiving signals transmitted from the

3 plurality of neighboring radio base stations, each
4 terminal station estimates a transfer function by
5 checking a correlation between each of the reception
6 signals and a known signal which is held by the terminal
7 station in advance and transmits the transfer function
8 to the radio base station, and
9 each radio base station changes the
10 directivity characteristic of the antenna on the basis
11 of the received transfer function.

16. A method according to claim 15, wherein
2 each radio base station transmits to the
3 intensive control station the transfer function
4 transmitted from each terminal station, and
5 the intensive control station calculates a
6 weight vector $W_d(i)$ ($i = 1$ to n : n is the total number
7 of terminal stations), using as parameters, the transfer
8 function and a predicted value $1/G(i)$ ($i = 1$ to n : n is
9 the total number of terminal stations) of a reception
10 level of each terminal station,
11 on the basis of the calculated weight vector
12 $W_d(i)$, calculates a sum of square errors between the
13 reception signals at the terminal stations which
14 simultaneously use the same communication channel with
15 the same frequency and same timing and desired signals
16 corresponding to the reception signals and repeatedly
17 calculates the weight vector $W_d(i)$ while repeatedly

18 changing the parameters until the sum of the square
19 errors becomes smaller than a predetermined threshold
20 value, and
21 determines the weight of the antenna of each
22 radio base station on the basis of the weight vector
23 $Wd(i)$ obtained when the sum of the square errors becomes
24 smaller than the threshold value.

17. A method according to claim 15, wherein
2 each radio base station transmits to the
3 intensive control station the transfer function
4 transmitted from each terminal station, and
5 the intensive control station calculates a
6 weight vector $Wd(i)$ ($i = 1$ to n : n is the total number
7 of terminal stations), using as parameters, the transfer
8 function and a predicted value $1/G(i)$ ($i = 1$ to n : n is
9 the total number of terminal stations) of a reception
10 level of each terminal station,
11 on the basis of the calculated weight vector
12 $Wd(i)$, calculates a sum of square errors between the
13 reception signals at the terminal stations which
14 simultaneously use the same communication channel with
15 the same frequency and same timing and desired signals
16 corresponding to the reception signals and repeatedly
17 calculates the weight vector $Wd(i)$ while repeatedly
18 changing the parameters until a maximum value of the
19 square errors at each terminal station becomes smaller

20 than a predetermined threshold value, and
 21 determines the weight of the antenna of each
 22 radio base station on the basis of the weight vector
 23 $Wd(i)$ obtained when the maximum value of the square
 24 errors becomes smaller than the threshold value.

18. A method according to claim 16, wherein
 2 equation (5) representing a weight vector $Wd(n)$ of a
 3 transmission system, which is to be given to the
 4 weighting circuit of the adaptive antenna of an n th
 5 radio base station, and equation (6) representing a
 6 predicted value $1/G(m)$ of the reception level of an m th
 7 terminal station, which is obtained by a directional
 8 pattern generated by the adaptive antenna, are
 9 alternately repeatedly calculated, and the weight vector
 10 $Wd(n)$ of a calculation result which has converged is
 11 used as a value of the weight to be given to each
 12 weighting circuit:

$$13 \quad Wd(n) = G(m) \left(\sum_{k=1}^K G(k)^2 Vd(k,n) Vd(k,n)^H \right)^{-1} Vd(m,n) \quad \dots (5)$$

$$14 \quad G(m) = \frac{\text{Re}(Wd(n)^H Vd(m,n))}{\sum_{k=1}^N (Wd(k)^H Vd(m,k) Vd(m,k)^H Wd(k)) + |\sigma(m)|^2} \quad \dots (6)$$

16 where

17 $\sigma(m)$: noise power of m th terminal station

18 Re : real number portion

19 suffix H: complex conjugate transposition

20
$$\mathbf{Wd}(n) = \begin{pmatrix} wd(n,1) \\ wd(n,2) \\ \vdots \\ wd(n,P) \end{pmatrix}$$

21

22

23 $wd(n,1)$ to $wd(n,P)$: weights for antenna

24 elements

25 P : number of antenna elements of n th base

26 station

27 $Vd(m,n)$: transfer function vector of downlink

28 communication between m th terminal station and

29 n th base station

30
$$\mathbf{Vd}(m,n) = \begin{pmatrix} vd(m,n,1) \\ vd(m,n,2) \\ \vdots \\ vd(m,n,P) \end{pmatrix}$$

31

32

33 $vd(m,n,1)$ to $vd(m,n,P)$: transfer functions of

34 antenna elements

35 N : number of base stations

36 K : number of terminal stations

37 Assume communication between n th base station

38 and m th terminal station

19. A method according to claim 17, wherein

2 equation (7) representing a weight vector $\mathbf{Wd}(n)$ of a

3 transmission system, which is to be given to the

4 weighting circuit of the adaptive antenna of an n th

5 radio base station, and equation (8) representing a

6 predicted value $1/G(m)$ of the reception level of an m th
 7 terminal station, which is obtained by a directional
 8 pattern generated by the adaptive antenna, are
 9 alternately repeatedly calculated, and the weight vector
 10 $Wd(n)$ of a calculation result which has converged is
 11 used as a value of the weight to be given to each
 12 weighting circuit:

$$13 \quad Wd(n) = G(m) \left(\sum_{k=1}^K G(k)^2 Vd(k,n) Vd(k,n)^H \right)^{-1} Vd(m,n) \quad \dots (7)$$

$$14 \quad G(m) = \frac{\text{Re}(Wd(n)^H Vd(m,n))}{\sum_{k=1}^N (Wd(k)^H Vd(m,k) Vd(m,k)^H Wd(k)) + |\sigma(m)|^2} \quad \dots (8)$$

16 where

17 $\sigma(m)$: noise power of m th terminal station

18 Re : real number portion

19 suffix H : complex conjugate transposition

$$20 \quad Wd(n) = \begin{pmatrix} wd(n,1) \\ wd(n,2) \\ \vdots \\ wd(n,P) \end{pmatrix}$$

23 $wd(n,1)$ to $wd(n,P)$: weights for antenna
 24 elements

25 P : number of antenna elements of n th base
 26 station

27 $Vd(m,n)$: transfer function vector of downlink
 28 communication between m th terminal station and
 29 n th base station

$$V_d(m,n) = \begin{pmatrix} v_d(m,n,1) \\ v_d(m,n,2) \\ \vdots \\ v_d(m,n,P) \end{pmatrix}$$

$v_d(m,n,1)$ to $v_d(m,n,P)$: transfer functions of antenna elements

N: number of base stations

K: number of terminal stations

Assume communication between nth base station and mth terminal station

20. A method according to claim 14, wherein

upon receiving signals transmitted from the plurality of neighboring terminal stations, each radio base station estimates a transfer function by checking a correlation between each of the reception signals and a known signal which is held by the radio base station in advance and changes the directivity characteristic of the antenna of the radio base station on the basis of the transfer function.

21. A method according to claim 20, wherein

each radio base station transmits the transfer function to the intensive control station, and the intensive control station calculates a weight vector $W_u(i)$ ($i = 1$ to n : n is the total number of terminal stations), using as parameters, the transfer

7 function and a transmission power value $G(i)$ ($i = 1$ to
8 n : n is the total number of terminal stations) set for
9 each terminal station,
10 on the basis of the calculated weight vector
11 $Wu(i)$, calculates a sum of square errors between the
12 transmission signals at the terminal stations which
13 simultaneously use the same communication channel with
14 the same frequency and same timing and desired signals
15 corresponding to the transmission signals and repeatedly
16 calculates the weight vector $Wu(i)$ while repeatedly
17 changing the parameters until the sum of the square
18 errors becomes smaller than a predetermined threshold
19 value, and
20 determines the weight of the antenna of each
21 radio base station on the basis of the weight vector
22 $Wu(i)$ obtained when the sum of the square errors becomes
23 smaller than the threshold value.

22. A method according to claim 20, wherein
2 each radio base station transmits the transfer
3 function to the intensive control station, and
4 the intensive control station calculates a
5 weight vector $Wu(i)$ ($i = 1$ to n : n is the total number
6 of terminal stations), using as parameters, the transfer
7 function and a transmission power value $G(i)$ ($i = 1$ to
8 n : n is the total number of terminal stations) set for
9 each terminal station,

10 on the basis of the calculated weight vector
 11 Wu(i), calculates a sum of square errors between the
 12 transmission signals at the terminal stations which
 13 simultaneously use the same communication channel with
 14 the same frequency and same timing and desired signals
 15 corresponding to the transmission signals and repeatedly
 16 calculates the weight vector Wu(i) while repeatedly
 17 changing the parameters until a maximum value of the
 18 square errors at each terminal station becomes smaller
 19 than a predetermined threshold value, and
 20 determines the weight of the antenna of each
 21 radio base station on the basis of the weight vector
 22 Wu(i) obtained when the maximum value of the square
 23 errors becomes smaller than the threshold value.

23. A method according to claim 21, wherein
 2 equation (9) representing a weight vector Wu(n) of a
 3 reception system, which is to be given to the weighting
 4 circuit of the adaptive antenna of an nth radio base
 5 station, and equation (10) representing a transmission
 6 power Gt(m) of an mth terminal station are alternately
 7 repeatedly calculated, and the weight vector Wu(n) of a
 8 calculation result which has converged is used as a
 9 weight to be given to each weighting circuit:

$$10 \quad Wu(n) = Gt(m) \left(\sum_{k=1}^K Gt(k)^2 Vu(k,n) Vu(k,n)^H \right)^{-1} Vu(m,n) \quad \dots (3)$$

$$G_t(m) = \frac{\text{Re}(W_u(n)^H V_u(m,n))}{\sum_{k=1}^N (W_u(k)^H V_u(m,k) V_u(m,k)^H W_u(k)) + (W_u(n)^H W_u(n) |\sigma(m)|^2)} \quad \dots (4)$$

where

$\sigma(n)$: input noise power of nth base station

$W_u(n)$: weight vector of nth adaptive antenna system

Re : real number portion

suffix H: complex conjugate transposition

$$W_u(n) = \begin{pmatrix} w_u(n,1) \\ w_u(n,2) \\ \vdots \\ w_u(n,P) \end{pmatrix}$$

$w_u(n,1)$ to $w_u(n,P)$: weights for antenna

elements

P: number of antenna elements of nth base

station

$V_u(m,n)$: transfer function vector of uplink

communication between mth terminal station and

nth base station

$$V_u(m,n) = \begin{pmatrix} v_u(m,n,1) \\ v_u(m,n,2) \\ \vdots \\ v_u(m,n,P) \end{pmatrix}$$

$v_u(m,n,1)$ to $v_u(m,n,P)$: transfer functions of

antenna elements

35 N: number of base stations
 36 K: number of terminal stations
 37 Assume communication between nth base station
 38 and mth terminal station

24. A method according to claim 22, wherein

equation (11) representing a weight vector $Wu(n)$ of a
 reception system, which is to be given to the weighting
 circuit of the adaptive antenna of an nth radio base
 station, and equation (12) representing a transmission
 power $Gt(m)$ of an mth terminal station are alternately
 repeatedly calculated, and the weight vector $Wu(n)$ of a
 calculation result which has converged is used as a
 weight to be given to each weighting circuit:

$$Wu(n) = Gt(m) \left(\sum_{k=1}^K Gt(k)^2 Vu(k,n) Vu(k,n)^H \right)^{-1} Vu(m,n) \quad \dots (3)$$

$$Gt(m) = \frac{Re(Wu(n)^H Vu(m,n))}{\sum_{k=1}^N (Wu(k)^H Vu(m,k) Vu(m,k)^H Wu(k)) + (Wu(n)^H Wu(n) |\sigma(m)|^2)} \quad \dots (4)$$

where

$\sigma(n)$: input noise power of nth base station

$Wu(n)$: weight vector of nth adaptive antenna
 system

Re : real number portion

suffix H: complex conjugate transposition

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